Search for Fissioning Isomers of ^{23}U and ^{23}Np by Using 14.8 MeV Pulse Neutrons (Memorial Issue Dedicated to the Late Professor Yoshiaki Uemura)

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Search for Fissioning Isomers of ^{237}U and ^{236}Np by Using 14.8 MeV Pulse Neutrons

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Search for fissioning isomers of ^{237}U and ^{236}Np was made by using the $^{238}U(n, 2n)$ and $^{237}Np(n, 2n)$ reactions with 14.8 MeV pulse neutrons, in the region of half-lives over 60 μs. The upper limits of $\sigma_{f,delayed}/\sigma_{f,prompt}$-values were obtained to be about 1×10^{-6} for both ^{237}U and ^{236}Np fissioning isomers with the region of half-lives studied.

I. INTRODUCTION

The fissioning isomerism has been observed in many transuranium nuclei near neutron numbers 146–148.[1~5] However, searches for fissioning isomers of uranium with odd A and of neptunium have been negative.[1,2,5~8] Preliminary search for fissioning isomer of ^{236}Np in the $^{237}Np(n, 2n)$ reaction with 14.8 MeV neutrons was reported in the previous work,[8] where the upper limit of $\sigma_{f,delayed}/\sigma_{f,prompt}$-value in the region of half-lives from 7 μs to 1 min was deduced to be about 1×10^{-5}. In the present work, search for fissioning isomer of ^{237}U was made in addition to further search of ^{236}Np, by using 14.8 MeV pulse neutrons. Short note for this work was reported in ref. 9.

II. EXPERIMENTAL PROCEDURE

Experimental procedure in this work is shown in detail in ref. 10. The neutrons were generated by using pulsed deuteron beams from a 2 MV Van de Graaff machine and Al-coated tritium metal target. Fission fragments were observed in each fission chamber of ^{238}U and ^{237}Np fixing at the target for neutron generation. The fission chambers were manufactured by the 20th Century Electronics LTD in the U.K. and they were characterized by the thickness and the active area of samples; for ^{238}U (depleted to 0.044% for ^{235}U) 1 mg. cm^{-2} and 144 cm^2 and for ^{237}Np 300 μg. cm^{-2} and 165 cm^2. The pulse operation for deuteron beams in the D–T neutron generation was made by using the system with double deflectors. The ratio of any residual beam intensity between bursts to the main beam intensity within a burst was obtained to be below 5×10^{-8}, by using a log-electrometer connected to the target.

In Fig. 1a, the accelerator and target rooms for JAERI 2 MV Van de Graaff machine are shown and in Fig. 1b the beam transport system for the pulse neutron generation is schematically described.

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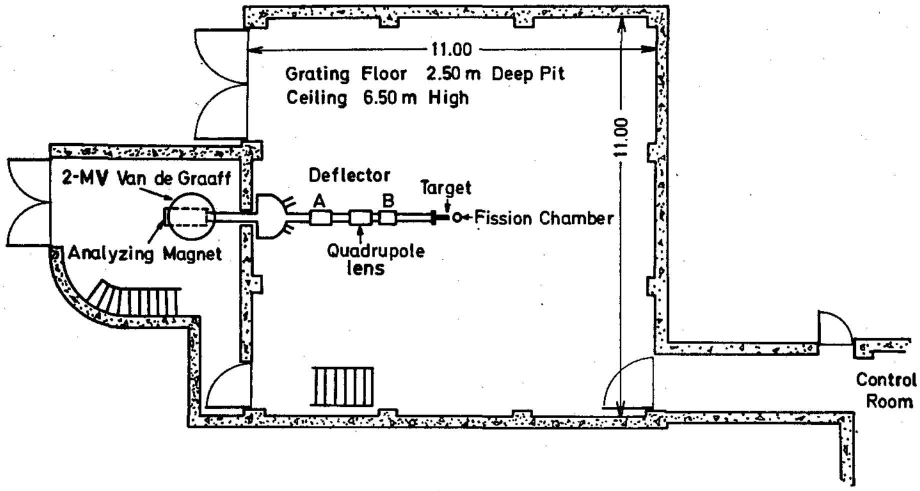

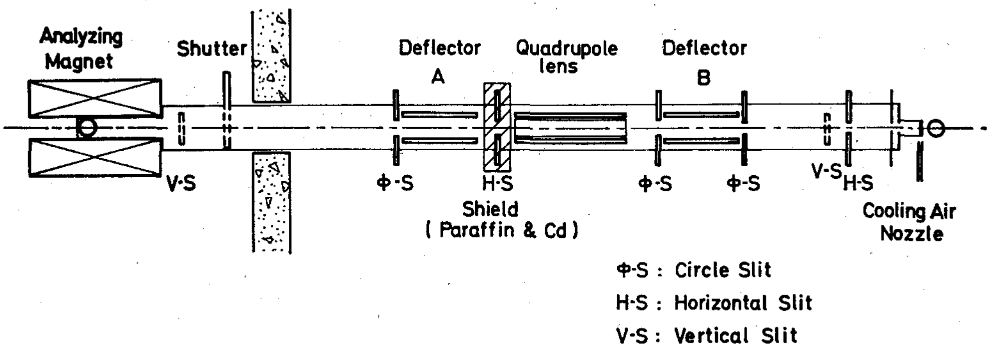

Figs. 1a and 1b. The accelerator and target rooms for JAERI 2 MV Van de Graaff machine. Fig. 1b describes the beam transport system for the pulse neutron generation.

In Fig. 2, a block diagram for the measurements is given. The upper part is related to the system of fission event measurements, and the lower part to the system pulsing the beams and to the beam current measurement. Fission pulses were discriminated from the alpha-particle pulses from the samples by using a rise time to height converter. The time distribution of fission pulses was measured by using three kinds of multiscaler mode of pulse height analyzer. Measurements were periodically carried out during and between the neutron bursts. The pulse duration was changed in the region from 60 μs to 10 s and the pulse duty was about ten percent. The measurement system was synchronized with the pulse neutron generation in the pulse program. The time relations among several parts of the circuit diagram in Fig. 2 are shown in Fig. 3. For each pulse operation mode defining by T_{prompt} and T_{delayed}, where T_{prompt} and T_{delayed} mean the burst duration and the time interval for measurements after a burst, respectively, $\sigma_{\mathrm{f,delayed}}/\sigma_{\mathrm{f,prompt}}$-values were obtained by assuming that there is any activity

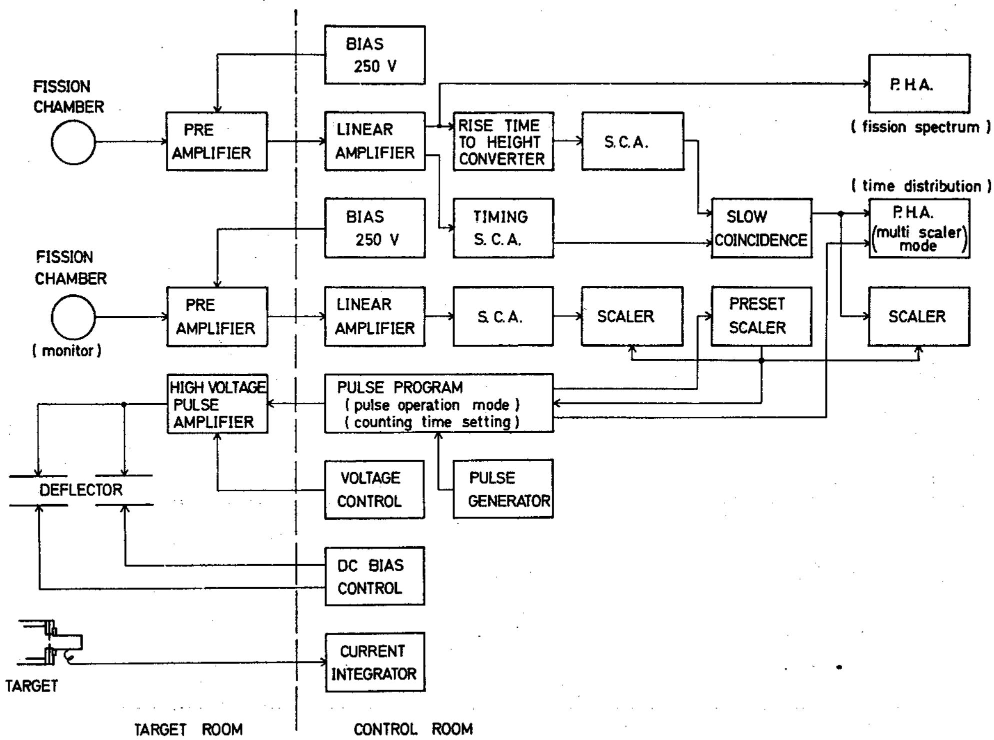

Fig. 2. A block diagram for the measurements.

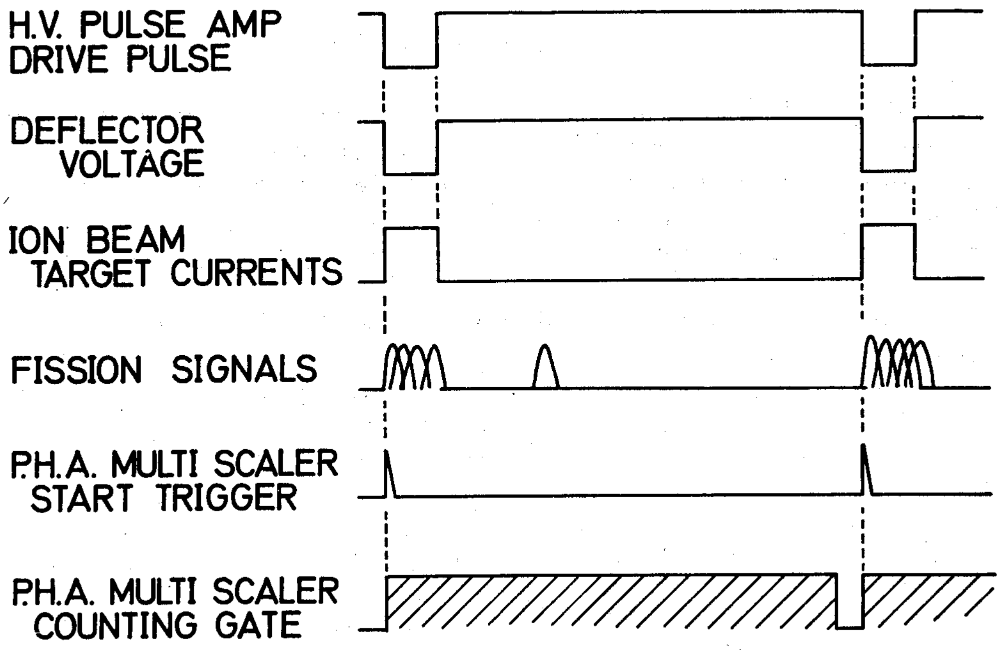

Fig. 3. The time relations among several parts of the circuit diagram in Fig. 2.

of a fissioning isomers with a characteristic half-life equal to T_{prompt}. These values are shown as a function of T (sec) in Fig. 4.

III. DISCUSSION

In Fig. 4, if there is any activity of a fissioning isomer with a characteristic half-life in the region from 60 μs to 10 s, we can expect at least one bump of the ratio rising

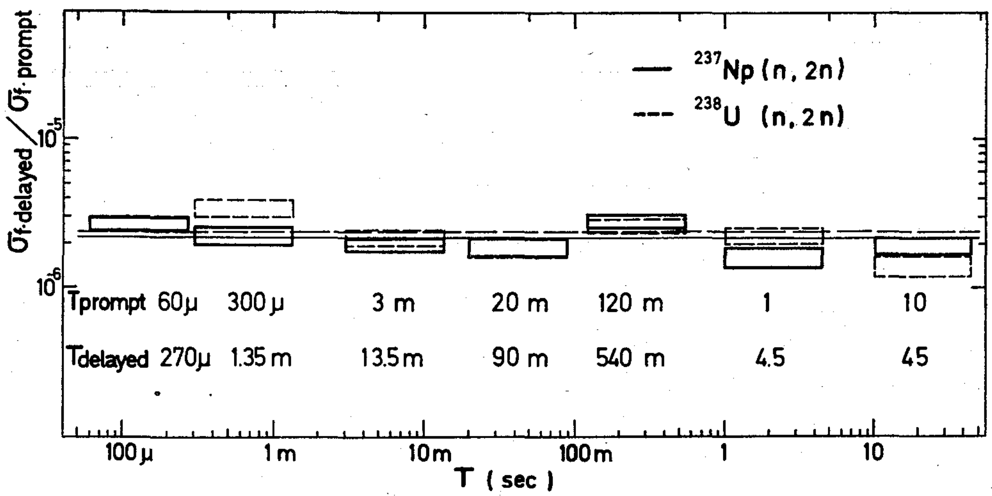

Fig. 4. $\sigma_{f,delayed}/\sigma_{f,prompt}$-value for each pulse operation mode. T_{prompt} and $T_{delayed}$ mean the burst duration and the time interval for measurements after a burst, respectively.

among pulse operation modes. Such bump, however, was not observed clearly and in addition any definite decay curve was not obtained in the time distribution for each pulse operation mode. It can be said that, for ^{237}U and ^{236}Np fissioning isomers with characteristic half-lives in the region studied, the upper limits of $\sigma_{f,delayed}/\sigma_{f,prompt}$-values are estimated to be about 1×10^{-6} corresponding to the deviations from average values of about 2×10^{-6}. The average value of about 2×10^{-6} may be attributed to the conditions of pulse neutrons, since the ratio of beam intensity between bursts to that within a burst is small as below 5×10^{-8}. Under the 1 hr irradiation with DC beams, the upper limits were deduced to be 4×10^{-7} for the ^{238}U(n, 2n) reaction and to be 2×10^{-8} for the ^{237}Np(n, 2n) reaction.

There is only one investigation on a known fissioning isomer by using the (n, 2n) reaction with 14 MeV neutrons; this is a well known discovery of 14 ms$-^{242}Am$ fissioning isomer by Flerov *et al.*[11] The $\sigma_{f,delayed}$-value of its fissioning isomer has been reported to be 140 μb. This value is converted into the $\sigma_{f,delayed}/\sigma_{f,prompt}$-value of 6×10^{-5}. This value is fairly larger than the upper limit values in the present work.

Recently the fissioning isomer of ^{237}Np (half-life of 40 ± 12ns) has been discovered and the $\sigma_{f,delayed}/\sigma_{f,prompt}$-value obtained is reported to be $10^{-8}-10^{-7}$.[12] This value is quite small in comparison with values larger than about 10^{-6} for the other known fissioning isomers. For the isomeric state of ^{237}Np in the secondary well of double humped barrier, it is considered that the penetration of the outer barrier leading to fission is not favored relative to that of the inner barrier, which would lead to gamma-decay in the first well.

Experimental evidences for the fissioning isomers of even-even actinide nuclei suggested that the fission branch of the ^{238}U shape isomer decay represented only one tenth of the total width for shape isomer de-excitation.[13] Following to this suggestion, Seattle group has fought their way to observe the gamma rays decaying from ^{238}U shape isomer in the secondary well to the states in the first well. Their results have been reported in the latest IAEA Fission Symposium in Rochester August 13–17 1973.[14] They have been successful to observe this kind of gamma rays of $E_\gamma=2.514$ and 1.879 MeV by using the ^{238}U(d, pn) ^{238m}U reaction. The 2.514 and 1.879 MeV gamma-lines were assigned likely to be the de-excitation gamma-rays from the lowest state with the spin-parity of 0^+, which may correspond to ^{238}U fissioning isomer, to the 2^+ member of the ground state rotational band at 45 keV and to the 1^- state of the lowest excited octuple state at 680 keV in the first well, respectively. The cross sections for the 2.514 and 1.879 MeV gamma-rays at $E_d=18$ MeV were obtained to be $90\pm25\,\mu$b and $40\pm20\,\mu$b, respectively. On the other hand, the cross section at $E_d=18$ MeV for the fission decay of ^{238}U fissioning isomer was reported to be 6 μb.[13] Considering the other decay gamma rays from this shape isomer to the states in the first well, the gamma branch from the shape isomer is estimated to be larger than 20 times of the fission branch.

For fissioning isomers of ^{237}U and ^{236}Np, it may be inferred that gamma-branch competes predominantly to the fission branch. However, the half-lives for these isomers can not be speculated in the present time.

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